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# **A Field Evaluation of Data Link Flight Information Services for General Aviation Pilots**

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The staff of the FAA William J. Hughes Technical Center, ACT-350

In memory of Damon Hart

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## EXECUTIVE SUMMARY

This report documents a field study of Data Link Flight Information Services (FIS) designed for use by general aviation (GA) pilots. The traffic information and weather services were developed by MIT Lincoln Laboratory under Federal Aviation Administration (FAA) sponsorship. The evaluation was conducted by the FAA Data Link Integrated Product Team (AND-650) with support from MIT Lincoln Laboratory. Resources for the evaluation were provided by the FAA and by the Aircraft Owner's and Pilots Association Air Safety Foundation (AOPA/ASF). The report is an independent assessment of the field study conducted by the Data Link Branch of the FAA William J. Hughes Technical Center.

### DATA LINK SERVICES AND EQUIPMENT.

The Data Link FIS package that was evaluated in this study included the Traffic Information Service (TIS), Text Weather Service (TWS), and Graphical Weather Service (GWS). TIS is intended to assist the pilot in the task of airborne collision avoidance by providing a graphical display of surrounding air traffic. The weather services are designed to provide near real-time weather information to GA pilots. TWS presents Surface Observations (SA) and Terminal Forecasts (FT) in National Weather Service (NWS) standard abbreviated text format. GWS is a national precipitation mosaic derived from ground-based weather radars. Portions of the mosaic are requested and displayed in the cockpit by selecting a location and radius. The display is a color-coded map which is capable of indicating three levels of precipitation intensity.

During the field study, the services were transmitted using Mode S Data Link. An operational Mode S sensor served as the source of TIS data for test aircraft and provided the primary Mode S Data Link communications to transmit weather requests from the aircraft and response uplinks from the FIS processor located at MIT Lincoln Laboratory. A Cessna 172 operated by AOPA was the test aircraft for the evaluation. The system installed on-board the aircraft included a Mode S transponder modified to include Level 3 Data Link capability. Display and processing functions were supported by a panel-mounted control/display unit (CDU) which included a color 3- by 4-inch cathode ray tube (CRT) and 10 bezel-mounted input keys.

### APPROACH.

The field study consisted of a series of structured evaluations in which 60 licensed GA pilots received individual training on the capabilities and use of the Data Link services. The pilots then flew a predefined scenario during which

they exercised the services. Detailed evaluation questionnaires were completed at the end of each flight.

## RESULTS.

The pilots who participated in this evaluation exhibited remarkable agreement in their evaluation of the Data Link FIS package. Over 90 percent of the pilots indicated that the system performed as expected during their test flights, that the system was reliable enough for operational use, and that the package of services enhanced the utility of GA aircraft.

The individual services also received high ratings. Almost all of the pilots indicated that the precipitation information would increase their confidence in "go-no go" decisions in flight planning, and that it would increase their confidence in decisions to deviate because of weather during a flight. Overall, 95 percent of the pilots felt that the Data Link weather services added to their understanding of the weather situation. At least 90 percent indicated that they would like to have regular access to both GWS and TWS, and nearly 100 percent noted that their overall impression of the two weather services was positive.

The pilot evaluations of TIS suggested that it accomplished its purposes of aiding the pilot in locating other aircraft and improving situation awareness. Nearly all of the pilots felt that the TIS helped them locate traffic that they might not have seen otherwise, and that it had helped them spot traffic earlier than they might have without the system. Over 90 percent indicated that their overall impression of TIS was positive and wanted regular access to the service.

Many of the pilots identified desirable improvements to the CDU interface and equipment layout for the FIS package. Commonly suggested changes were relocation of the CDU, improvements in the readability of the display, and input control modifications.

The relatively short duration of the evaluation flights and the lack of repeated experiences with the system prevented the pilots from achieving a strong consensus on some issues. These included (1) the effects of the age of the GWS weather data, (2) the effects of compression induced distortion in the GWS maps, and (3) whether the "head down" time or workload requirements of the system were too high. In addition, the field study was not specifically designed to determine whether pilots would make appropriate use of GWS and TIS under boundary operational conditions where improper use of the system could negatively affect pilot decisions. However, some participant comments noted the potential for misuse caused by failures to consider the age of the precipitation data and the lack of geographical precision in the compressed

maps. Improper use of TIS could also occur if a pilot used it as the sole basis for an avoidance maneuver at close range .

### RECOMMENDATIONS.

The pilots who participated in this study expressed a high level of acceptance for the Data Link FIS package, and indicated that the services offer a significant potential for improvements in the safety and utility of GA operations. For these reasons, it is recommended that the FAA and industry actively pursue the implementation of this Data Link application and the development of operational airborne equipment that is affordable and effective.

As a part of the continued development process, further work should be done to define minimum pilot interface requirements for the Data Link FIS package which promote rapid and accurate pilot interaction with the system. In conjunction with efforts to develop these requirements, research is needed to determine whether the pilot workload and "head-down" time demands of the system are acceptable, and if such demands are mitigated by long-term use.

Research also should be conducted to ensure the effectiveness of training materials, warnings, and instructions intended to prevent potential pilot errors caused by the misuse of the GWS or the TIS.

## 1. INTRODUCTION.

### 1.1 PURPOSE.

This report presents an analysis of results that were obtained from a field evaluation of Data Link Flight Information Services (FIS) designed for use by general aviation (GA) pilots. The traffic information and weather services were developed by MIT Lincoln Laboratory under Federal Aviation Administration (FAA) sponsorship.

The evaluation was conducted by the FAA Data Link Integrated Product Team (AND-650) with support from MIT Lincoln Laboratory. Resources for the evaluation were provided by the FAA and by the Aircraft Owner's and Pilots Association Air Safety Foundation (AOPA/ASF).

This report was prepared by the Data Link Branch (ACT-350) of the FAA William J. Hughes Technical Center. Much of the introductory and background material presented here was derived from information contained in the test plan for the field evaluation (Chandra and Bernays, 1995). The goal of the report is to provide an independent assessment of the field evaluation based on an analysis of the formal AOPA/ASF structured evaluation results and on direct observations made during data collection site visits. The report does not address feedback obtained from individuals who had the FIS package available for longer term use and evaluation.

### 1.2 BACKGROUND.

Under tasking from the FAA, MIT Lincoln Laboratory has been engaged in a multiyear program to develop Mode S Data Link applications for GA pilots. Three primary FIS products that have been generated by the program include Traffic Information Service (TIS), Text Weather Service (TWS), and Graphical Weather Service (GWS). This package of services has undergone technical development and testing by MIT Lincoln Laboratory and independent technical testing by the FAA Technical Center. It has also been demonstrated in commercial GA avionics modified by the manufacturer.

The purpose of TIS is to assist the pilot in the task of airborne collision avoidance by aiding in the visual acquisition of surrounding air traffic. The traffic information is presented in a graphical format similar to that provided by the Traffic Alert Collision Avoidance System Version 1 (TCAS-1). When a request for TIS is received from the pilot via Data Link, the cockpit traffic display is updated automatically on every scan of the

Mode S sensor (approximately every 5 seconds). The relative altitude and position of transponder-equipped aircraft within 5 nautical miles (nmi) and  $\pm$  1200-foot altitude of the requesting aircraft are displayed. In addition, those aircraft which represent a potential collision threat are identified by visual and aural alerts. No conflict resolution advisory is provided. The TIS algorithms hosted in the Mode S sensor use track reports provided by Mode S radar surveillance to generate traffic information.

The remaining two services are designed to provide near real-time weather information to GA pilots. TWS presents Surface Observations (SA) and Terminal Forecasts (FT) in National Weather Service (NWS) standard abbreviated text format. SAs are hourly updates of airport surface conditions, while FTs provide 24-hour forecasts. GWS is a national precipitation mosaic derived from ground-based weather radars. Mosaic updates were available every 15 minutes during most of the evaluation flights. However, updates at 5-minute intervals were introduced for some of the flights. When requesting GWS, the pilot selects a portion of the national mosaic for display in the cockpit by specifying a center point and radius (25, 50, 100, or 200 nmi). The display is a color-coded map which is capable of indicating three levels of precipitation intensity.

### 1.3 FIELD EVALUATION OBJECTIVES.

The overall goal of the field evaluation was to obtain feedback about the perceived operational suitability, utility, and value of the Data Link FIS package from pilots. The intended application of the findings is to determine the benefits of making these services available to owners and operators of GA aircraft, and to guide further refinement of the services.

## 2. DATA LINK SYSTEM DESCRIPTION.

### 2.1 GROUND SYSTEM.

The ground facilities used in the field evaluation included (1) the Mode S sensor at Dulles International Airport (IAD), (2) the Data Link Transmit/Receive (T/R) ground station at the Frederick, Maryland Airport (FDK), and (3) the FIS processor at MIT Lincoln Laboratory.

The primary function of the commissioned Mode S sensor at IAD is to maintain surveillance on all transponder-equipped aircraft within its line-of-sight coverage area. For the evaluation, the sensor served as the source of TIS data for test aircraft and provided the Mode S Data Link

communications to transmit weather requests from the aircraft and response uplinks from the FIS processor.

The TIS algorithms in the sensor detected those aircraft requesting TIS, computed the relative range, bearing, and altitude of intruder aircraft, and sent traffic reports to the requesting aircraft. Operation of the TIS in the sensor was automatic and required no interaction with air traffic controllers.

FIS weather requests through the Mode S sensor were handled as standard length Mode S downlink Data Link messages. A dedicated telephone line forwarded the downlinks to the FIS processor in Lexington, MA, and returned the appropriate reply to the sensor. The FIS replies were then sent to the aircraft via Mode S uplink extended length messages. Since a single reply could contain up to 4800 bits, replies were broken into 1280 bit packets sent at intervals of approximately 5 seconds (one packet per sensor scan).

In addition to the Mode S sensor, FIS weather communications were provided by the Data Link T/R ground station at FDK. The T/R station was a TCAS unit that was modified to support Mode S Data Link protocols. No surveillance was provided by the T/R station. Like the Mode S sensor, when a downlink request from a test aircraft was detected, the T/R station read the message and forwarded it to the FIS processor by telephone line. The FIS processor reply was sent to the aircraft using the same Mode S protocols used by the sensor.

The primary differences between a T/R station and a Mode S sensor are range and speed of service. Although the T/R station provides coverage to the surface, its range is restricted to between 10 and 20 nmi. A Mode S sensor's range is much greater, but its coverage does not reach the surface at extended ranges. The T/R station can also respond to requests roughly five times faster than a Mode S sensor because it uses an omnidirectional antenna which is not subject to the scan delay of a rotating antenna. In the Dulles configuration, the ground station was programmed to give priority to the Mode S sensor when the target was in range of both the sensor and the T/R station. The T/R station was able to detect the presence of an FIS downlink within 500 milliseconds (ms) of being posted in the aircraft transponder, and was able to transmit one 1280-bit extended length uplink message each second. It should be noted that the T/R station was used in the evaluation to facilitate ground testing and training, and is not planned for deployment as part of an FIS implementation.

The FIS processor at MIT Lincoln Laboratory maintained a local copy of the graphical and textual weather databases to support GWS and TWS. Requests received via telephone line from either the Mode S sensor or the T/R ground station were first screened by the FIS processor to insure that they had been sent by an authorized test aircraft. The appropriate reply was then encoded and sent to the facility (Mode S sensor or T/R station) from which it originated. The Mode S sensor was connected to the FIS processor via an ATC communications port using protocols defined in the Mode S interface standard. The T/R station and the FIS processor communicated over a dedicated land line using RS-232 asynchronous protocols. The FIS processor received text and graphical weather updates from WSI via satellite downlink.

## 2.2 AIRBORNE SYSTEM.

A Cessna 172 operated by AOPA served as the test aircraft for the evaluation. The system installed on-board the test aircraft included a Bendix King KT 70X panel mounted Mode S transponder. The transponder was modified by the manufacturer to include Level 3 Data Link capability. Display and processing functions were supported by a panel-mounted ARNAV MFD 5100 control/display unit (CDU) and a remote mounted line replaceable unit (LRU).

The ARNAV CDU includes a color Sony 3- by 4-inch cathode ray tube (CRT) and 10 bezel-mounted input keys. The ARNAV LRU contains an Intel 486-based processor board with math coprocessor. The airborne Data Link software was hosted on a memory card in the LRU which can be replaced to install software upgrades. The LRU communicated with the Data Link transponder via a dedicated serial port.

The Data Link pilot interface was specifically designed for the ARNAV CDU with its soft-key capability to access menu pages. The variable functions of the keys for each page were designated by adjacent text menu items displayed on the CRT. These functions permitted the user to enable/disable TIS and enter various text and graphical weather requests. The airborne software included an internal database of airport and VOR locations from which weather may be requested.

## 3. EVALUATION METHODOLOGY.

### 3.1 SUMMARY OF APPROACH.

This study consisted of a series of structured evaluations in which licensed GA pilots received individual training on the capabilities and use of the

Data Link services, and flew a predefined scenario during which they exercised and evaluated the services. Each evaluator was accompanied by a safety pilot during their flight. Pilot background and experience information as well as initial impressions of the system were obtained following the training session. Detailed evaluation questionnaires were completed at the end of each flight.

### 3.2 EVALUATION ISSUES.

The items presented on the detailed questionnaire were designed to address the following evaluation issues:

- a. System reliability, availability, and responsiveness.
  - Are the services provided as requested in a timely manner?
- b. Utility of the Data Link services for GA Operations.
  - Does the information aid the pilot in making decisions?
- c. Subjective evaluation of the usability of the pilot interface, especially in single pilot operations.
  - Are users able to learn to use the CDU, and do they use it effectively?

The three items listed above can be categorized as general human factors questions concerned with the timeliness of service delivery, the useability of the pilot interface, and the value of the information provided to pilots by the service. Based on these general issues, specific human factors questions are also examined in this report with reference to some of the unique technical characteristics and limitations of the three components of the FIS package. These questions include:

- a. Did the location of the CDU on the instrument panel affect data entry or readability of the display?
- b. Were data entries used to request services and select information intuitive and easy to perform in the context of on-going flight tasks?
- c. Was the information provided by each service provided in a format which provided rapid and accurate assimilation?
- d. Did alert and displays provide rapid and reliable notification to the pilot?



- e. What changes to the inputs and displays will be necessary or useful?
- f. What additional features or functions should be included in the design of each service?
- g. Was the training provided adequate to prevent misuse or misinterpretation of graphical weather data? (e.g., inappropriate use of compressed weather maps to penetrate weather.)
- h. Was training on the limited precision of the compressed weather images and displays of the age of the text report or map adequate to prevent inappropriate use of graphical and text weather services?
- i. Was training adequate to prevent inappropriate use of the TIS display?

### 3.3 FIELD EVALUATION PARTICIPANTS.

Participants in the formal structured evaluation flights at Frederick, MD, were 60 licensed pilots. A descriptive profile of the group's flight experience is presented in table 1.

TABLE 1. PARTICIPANT PILOT CERTIFICATION AND FLIGHT EXPERIENCE

<b>Highest Pilot Certification</b>	
Private	28.3%
Instrument	15.0%
Commercial	8.3%
Multi-engine	10.0%
Flight Instructor	23.3%
Airline Transport	15.0%
<b>Flight Experience</b>	
Total Hours Range	60 - 25,000
Total Hours Median	2012
Cross Country Range	15 - 24,000
Cross Country Median	1157
Instrument Range	0 - 3,000
Instrument Median	218

The recency of flight experience within the group ranged from 26.6 percent who had flown less than 50 hours during the past year to 21.7

percent who had flown over 150 hours during the same period. A majority of the pilots (51.7 percent) had flown between 50 and 150 hours.

### 3.4 STRUCTURED EVALUATION PROCEDURES.

#### 3.4.1 Preflight Training.

After reading and signing an informed consent document describing the study, pilot participants received a 30- to 40-minute training presentation. This presentation introduced the pilot to the Mode S Data Link system as implemented at IAD and described service coverage area limitations. Detailed instruction on each of the services covered: (1) TIS display symbology, status messages and cautions; (2) GWS images, the source and content of the data, error messages and cautions, and the effects of data compression on the precision of the displayed map; and (3) the content of the TWS products. Training techniques included inspection of sample compressed and raw weather images for GWS, and ground-based practice with the avionics. The training presentation concluded with a review of the evaluation materials. Following the training session, all participants completed a background questionnaire which solicited information on the pilot's age and flight experience.

#### 3.4.2 Flight Scenario.

Prior to the evaluation flight, the subject pilots received a preflight briefing from the safety pilot. The briefing outlined the route of flight and the tasks that the pilot would be asked to perform while airborne. The plan for each flight called for the pilot to depart the FDK and to fly direct to Martinsburg (MRB) very high frequency omnidirectional range collocated with tactical air navigation (VORTAC); then direct to the Armel (AML) VORTAC 342° radial, 15 nmi fix; then direct to Frederick. The pilots were instructed to maintain an altitude of 2,000 feet. If desired, the pilot could contact Dulles Approach on 126.1 when inbound from Martinsburg for traffic advisories.

During the flight, the safety pilot directed the subject pilot to perform several tasks which exercised the three Data Link services. These included making a minimum of four requests for the GWS, and answering safety pilot questions which probed the participant's geographical understanding of the displayed area relative to his current position, the age of the map, the levels of precipitation shown, and the weather movement. The participants were also directed to request TWS reports and to note their agreement with the GWS data. Finally, the participants

were asked to call out traffic identified by the TIS and to indicate visual sighting.

### 3.4.3 Data Collection.

In addition to the background questionnaire administered during training, each pilot completed a structured flight questionnaire at the conclusion of the flight (see appendix A). The structured flight questionnaire included 59 questions and subquestions divided into five evaluation categories: (1) weather services; (2) traffic information service; (3) CDU interface; (4) training materials; and (5) overall system. A majority of the questions were phrased as statements to be rated on a 5-point scale. Additional questions solicited written comments, or ratings on other ordinal scales.

## 4. RESULTS.

The data obtained from the 60 completed questionnaires are documented in appendix A. As discussed in section 3.4.4, most of the items presented in the questionnaire were formatted as declarative statements. The respondent answered the questions by indicating his or her level of agreement with each statement on a 5-point scale with verbal anchors at the extremes and mid-point of the scale: (1) Strongly Disagree, (3) Neutral, (5) Strongly Agree. Indications of the statistical significance of the findings discussed below are based on analyses using the Chi-Square statistic where the number of observed responses falling in the two “agree” categories (4 and 5) were compared to the number of responses in the two “disagree” categories (1 and 2). The test of significance was based on the likelihood that the observed distribution of responses across the agree/disagree dimension differed from a randomly distributed set of responses. Unless otherwise indicated, findings discussed below were statistically significant ( $p \leq .05$ ). All cases where a large number of the evaluators responded to an item by indicating “no opinion/neutral” are explicitly addressed in the text.

### 4.1 WEATHER SERVICES.

#### 4.1.1 Use of the Weather Services.

Four of the questionnaire items addressed the utility of the weather services as aids to flight planning and decision making. Ninety-two percent of the pilots indicated that the precipitation information would increase their confidence in “go - no go” decisions, while 95 percent felt that it would increase their confidence in decisions to deviate because of weather during a flight. Overall, 95 percent of the pilots felt that the Data

Link weather services added to their understanding of the weather situation.

The pilots provided a written response when asked to identify those aspects of the weather information that would be most useful when planning an in-flight deviation. Of the 53 pilots who indicated a preference, 58 percent felt that the GWS precipitation map data relative to their current geographical position, or the ability to determine weather movement using multiple maps would be most useful. An additional 28 percent indicated that both the GWS maps and portions of the TWS text data would be most useful. Only 13 percent suggested that the use of data offered by TWS alone would be most useful.

#### 4.1.2 Usability and Utility of GWS.

The GWS display presents the weather information in a "north-up" geographical orientation. Ninety-seven percent of the pilots indicated that they were able to relate the precipitation information to their present position using this display. However, 12 of the 60 pilots reported some difficulty in doing so, or recommended an alternative display format. Three pilots indicated an explicit preference for a display oriented in relationship to their aircraft's current track.

When asked whether they were able to judge how the GWS precipitation display would affect their flight, 92 percent of the pilots responded positively without reservation. The remaining pilots also indicated that they were able to judge the effects of the precipitation data, but noted the desirability of additional information. Suggestions included the addition of landmarks such as airport locations on the display, a finer breakdown of precipitation levels, and the need for other data to support their judgments (e.g., TWS).

Questionnaire items concerning the age of the GWS precipitation data and the effects of data compression revealed no significant agreement among the pilots. Thirty-seven percent felt that the 8- to 22-minute age of the maps did not reduce the utility of the displayed information. However, 35 percent suggested that it would have a negative impact, and 28 percent were neutral regarding the age of the precipitation data.

When asked to evaluate the effects of compression-induced distortion on the utility of GWS, 38 percent suggested that it had no effect, while 17 percent felt that it would reduce its usefulness. Forty-five percent were neutral. This equivocal response may have been largely a result of the minimal experience with GWS provided by the evaluation flight. The

effects of distortion would be expected to emerge only after the pilots had used the system over several flights and personally experienced the potential differences between the displayed maps and actual weather conditions. This explanation of the findings is reinforced to some extent by responses to an item which inquired about the agreement of the precipitation data with other available sources of information. Although 83 percent of the pilots indicated that there was general agreement, 17 percent were neutral, suggesting a lack of adequate experience to answer the question in a confident manner.

A modification to the GWS software was introduced for the final 20 of the 60 evaluation flights. This modification changed the GWS compression technique from the poly-ellipse algorithm to the so-called Huffman algorithm. Previous simulation research had shown that the images produced by the Huffman algorithm were more acceptable to subject pilots. Results of the post-flight questionnaires completed before and after the software change revealed no appreciable differences in responses to items concerning the GWS.

In a final question regarding the utility of the weather services, the pilots were asked whether their use of the services had changed with experience. Twenty-six of the participants indicated that the services had become easier to use or that their confidence in the information provided had increased. The remaining pilots either left this item blank, or responded "not applicable" or "no." Rather than denoting a problem with the weather services, this apparent disparity in opinion probably reflects the inability of most of the pilots to develop an advanced level of familiarity with the system over the 1-hour duration of the evaluation flight. It may also reflect the fact that the flights were conducted under VFR conditions in order to facilitate evaluations of TIS. As a consequence, the GWS requests were typically for locations outside the evaluation flight area.

#### 4.1.3 Overall Evaluation of GWS and TWS and General Comments.

Several questionnaire items were directed at an overall evaluation of the weather services' perceived value and importance. One hundred percent of the pilots indicated that their overall impression of GWS was positive, while 97 percent had a similarly positive impression of TWS. Ninety-seven percent of the pilots also agreed that that they would like to have access to GWS all the time, while 90 percent desired regular access to TWS. Finally, near-term availability of GWS and TWS were viewed as important to GA operations by 88 percent and 85 percent of the pilots, respectively.

When asked to identify other weather information that they would like to see provided via Data Link, the pilots offered a range of responses. Among the most common of these were pilot reports (PIREPS) notices to airmen (NOTAMS), winds aloft, and any other weather information available from Flight Service. General comments solicited by an open-ended questionnaire item yielded a clear majority of positive responses regarding the weather services, which often emphasized the improvement in safety that would be provided through weather accident avoidance. Other comments suggested general changes to the Data Link interface (see section 4.3) or a desire for improvements to the services. The latter included issues regarding limitations of GWS related to the age of the weather maps or the precision of the data that are provided in the compressed images. While these comments were generated by a minority of the pilots, they suggest some concerns regarding the utility of the system for short-term decision making about nearby geographical locations, and the potential misuse of GWS by some pilots as an equivalent of real-time weather radar.

## 4.2 TRAFFIC INFORMATION SERVICE.

### 4.2.1 Effectiveness of TIS.

Three items on the questionnaire were designed to determine whether the traffic display accomplished its purposes of aiding the pilot in locating other aircraft and improving situation awareness. Ninety-eight percent of the pilots felt that the TIS helped them locate traffic that they might not have seen otherwise, and 92 percent indicated that it had helped them spot traffic earlier than they might have without the system. Ninety-three percent of the participants agreed that the traffic display improved their awareness of the traffic situation.

### 4.2.2 TIS Usage Issues.

Three questionnaire items focused on potential problems with the use of the traffic display. When asked whether the limitations of the display hampered their traffic search, 73 percent of the pilots indicated that this was not the case. However, for reasons which are not readily apparent, 22 percent were neutral on this issue. It is possible that some of these pilots may not have had sufficient opportunity to experience TIS alerts during their flights.

To determine whether the TIS display affected the amount of time that the pilots normally devote to visual monitoring for traffic, they were asked if

they looked outside for traffic as much as they would otherwise. A statistically significant 62 percent of the pilots disagreed with the statement that they did not monitor out the window as often. However, 23 percent felt that TIS reduced the frequency with which they scanned for traffic outside, and 15 percent were neutral. The practical significance of the possibility that some pilots may rely on TIS to replace a portion of their normal outside visual search activity is impossible to determine from the available data.

Finally, the pilots were queried regarding the lack of precise correlation between an outside view of a target aircraft's position and its position shown on the TIS display. Such disparity is attributable to Mode S antenna rotation effects and Data Link transmission delays. Sixty-two percent of the pilots disagreed with the statement that the Data Link traffic information sometimes conflicted with information from other sources (e.g., looking out the window). Seventeen percent agreed that they did notice the conflict, while 21 percent were neutral. None of the available results suggest that this conflict presented any problems for the pilots during the test flights.

#### 4.2.3 Overall Evaluation of TIS and General Comments.

As with the weather services, the pilots were asked to provide an overall evaluation of TIS. Ninety-eight percent of the pilots indicated that their overall impression of the Data Link traffic display was positive, and 92 percent indicated that they would like to have TIS available all the time. Eighty-five percent of the pilots felt that near-term availability of TIS is important to GA operations.

General written comments reflected this overall positive response to TIS with several pilots noting a personal experience in which the display allowed them to locate potential threat aircraft during the evaluation flight. Other comments suggested modifications to the display. These included the desire for a more prominent audible alert for threat targets (two pilots), and for a capability to alter the range of coverage in en route and terminal environments, and/or to select the range at which threat alerts are provided (five pilots).

#### 4.3 CDU PILOT INTERFACE.

Seven questionnaire items addressed the useability of the CDU interface and the task demands associated with its operation. Ninety-three percent of the pilots disagreed with the statement that the CDU takes a long time to learn, and felt that the CDU was easy to use once understood.

Similarly, 98 percent indicated that they were able to get desired information from the display when it was required. Eighty-three percent said that they were able to get the information desired without making errors.

Only 2 percent of the participants felt that the system placed too much workload on the pilot in single pilot operations. However, there was no statistically significant agreement among the pilots regarding requirements of the system for excessive "head-down" time in single pilot operations. While 43 percent felt that use of the CDU did not demand too much time away from visual scanning and monitoring out of the window, 22 percent agreed that head-down time requirements were too high, and 33 percent were neutral on this issue.

In addition to the typical difficulties associated with learning to use any complex avionics equipment, "head-down" time requirements and error rates in the use of an aircraft's computer-human interface are commonly affected by the design of the controls and displays. When asked if they would prefer a different layout/design of the CDU, pilot responses displayed wide variability with no statistically significant agreement within the group. Thirty percent of the pilots preferred no changes, 33 percent were neutral, and 37 percent preferred changes to the CDU interface and equipment layout.

When asked to suggest improvements to the CDU interface, a majority of the pilots listed changes, with many offering multiple suggestions. These modifications are presented in appendix A and are summarized in table 2 in order of frequency of occurrence in the pilots' comments.

#### 4.4 FIS TRAINING REQUIREMENTS.

A major issue in fielding any new aircraft equipment that can influence pilot decision making is the amount and type of training that will be required to promote proper use of the system. For this reason, the questionnaire included several items which solicited the pilots' opinions on training requirements for the Data Link FIS. Ninety-five percent of the pilots agreed that the training that they had received prior to the evaluation flight was appropriate. Negative comments on the training methodology (five pilots) focused on the limited value of the video tape presentation.



TABLE 2. SUGGESTED CDU INTERFACE CHANGES

Suggested Design Change	Number of Pilots
Change Location of CDU for Accessibility/Readability	33
Improve Display Contrast/Brightness, Reduce Glare	12
Change Method or Type of Control Used to Enter Weather Location	10
Improve Key Accessibility/Increase Size or Spacing	5
Increase Size of Displayed Alphanumeric Characters	3
Improve Command Logic	3
Reduce Cursor Response Lag	3
Improve Discriminability Between Stored and Recently Uplinked Weather Maps	1

A significant 73 percent of the participants agreed that the typical GA pilot should receive some form of training on the use of the Data Link services. However, 15 percent were neutral and 12 percent disagreed. Table 3 summarizes the pilots' preferences for the type of training appropriate for five key FIS topics. In general, the results suggest a preference for video based training, or for video training combined with written and/or orally presented material. However, the data indicate that requirements for oral presentations or written material may be greatest for explanations of the weather map compression algorithms, the coverage limits, and the text weather products.

**TABLE 3. PILOT PREFERENCES FOR FIS TRAINING METHODS**

	<b>Written Only</b>	<b>Oral Only</b>	<b>Video Only</b>	<b>Written /Oral</b>	<b>Written /Video</b>	<b>Oral/ Video</b>	<b>All 3 Modes</b>
<b>Explain TIS</b>	8%	10%	38%	0%	15%	17%	12%
<b>Precipitation Display</b>	7%	15%	38%	2%	15%	16%	7%
<b>Compression Algorithms</b>	29%	13%	29%	0%	9%	15%	5%
<b>Coverage Limits</b>	24%	20%	22%	8%	8%	10%	8%
<b>Text Wx Products</b>	17%	17%	29%	7%	14%	9%	7%

Ninety percent of the pilots felt that training should include practice with the system on the ground, and four of the participants indicated a requirement for airborne practice with a qualified technician or instructor.

#### 4.5 OTHER QUESTIONNAIRE ASSESSMENTS.

##### 4.5.1 Overall System Evaluation.

A final group of questionnaire items was designed to assess the pilots' general opinion of the Data Link services. Overall, the participants assigned high ratings to the system. Ninety-two percent agreed that it performed as expected and 95 percent felt that they received the requested services in a timely manner during the evaluation flights. Only one of the pilots felt frustrated with the system because significant problems were encountered during the flight. Ninety-three percent of the pilots indicated that the system was reliable enough for operational use, while 95 percent felt that the package of services enhanced the utility of GA aircraft.

##### 4.5.2 Utility of the Services.

The utilities of the individual services were rated on a 5-point scale ranging from 1 (low utility) to 5 (high utility). The TIS, and the TWS surface observations and terminal forecasts all received a median utility rating of "5" on the scale. The graphical weather precipitation map was rated only slightly lower, receiving a median rating of "4" from the pilot group.

When asked to identify those users who would benefit most from the Data Link FIS package, the pilots offered a range of responses. Over 30 percent of the participants felt that all pilots would benefit from the services. Of those pilots who qualified their comments, TIS was seen as valuable to the broadest section of the pilot community, especially in high traffic density environments. Conversely, the weather services were seen as most beneficial to more experienced pilots, those who fly frequently, cross country fliers, and instrument-rated pilots.

A small group of the respondents indicated that the benefits would be limited for inexperienced pilots who may find that the system is distracting or requires too much "head-down" time.

#### 4.5.3 Acceptable Costs.

Assuming that the services would be provided at no charge, the pilots were asked (1) what would be a reasonable cost for the equipment to receive Data Link FIS, and/or (2) how much extra it should cost to rent an aircraft with the necessary equipment. The results are summarized in table 4 as cumulative percentages of the respondents who specified purchase or rent costs at, or below, the indicated maximum charges. If the data from the participants in the evaluation are considered representative of the general pilot population, the table suggests that over 45 percent of pilots would buy the FIS Data Link equipment at a price of \$5000, and that a similar percentage would pay an additional \$10 per hour to rent an equipped aircraft.

TABLE 4. MAXIMUM REASONABLE COSTS TO BUY/RENT DATA LINK EQUIPMENT

<b>Selling Price</b>	<b>Cumulative Percent of Pilots</b>	<b>Added Hourly Rental Price</b>	<b>Cumulative Percent of Pilots</b>
≤ \$1000	100	≤ \$2	100
≤ \$2000	97	≤ \$3	85
≤ \$3000	69	≤ \$5	81
≤ \$4000	60	≤ \$8	50
≤ \$5000	46	≤ \$10	46
≤ \$6000	26	≤ \$15	12
≤ \$7000	17		
≤ \$8000	9		
≤ \$10000	6		

#### 4.6 SITE VISIT OBSERVATIONS.

As a part of the independent evaluation of the Data Link FIS field study, representatives of the FAA Technical Center's Data Link Branch (ACT-350) made site visits to AOPA in Frederick, MD. The visits included opportunities to interview the safety pilot, examine the FIS pilot interface, and observe pilot training and in-flight activities.

The site visits indicated that the evaluations were conducted in accordance with good scientific practice. Since a single certified flight instructor served as the trainer and safety pilot for all 60 flights, variability in the results that could have been induced by differences in individual approach and style were essentially eliminated. The observed procedures closely followed the methodology outlined in the published research plan. In addition, the safety pilot's use of a checklist in conducting the activities during the flights ensured a high level of consistency from flight to flight. While daily variations in weather and traffic undoubtedly produced variations in the experiences received by the participating pilots with the weather and traffic information services, it is unlikely that these differences significantly biased the results obtained with the questionnaire.

The site visits also suggested that limitations of the structured evaluation flight scenario may have affected the pilots' abilities to confidently respond to some of the questionnaire items. There was no significant agreement among the pilots regarding the effects of the age of the graphical weather maps on their utility. Likewise, while most of those responding felt that compression-induced distortion did not affect the utility of the maps, 45 percent of the pilots were not able to form an opinion (marked "neutral" on the rating scale). These equivocal assessments probably were a result of the limited number of applications of GWS that could be made during the relatively short evaluation flights. Repeated experiences with the system during cross country flights under varying weather conditions would have been necessary to provide the pilots with a basis for forming solid opinions about the utility of the weather maps and the effects of age and distortion.

The assessment of distortion effects also may have been affected by the fact that GWS evaluations were largely based on requests for weather outside the evaluation flight area (see section 4.1.2).

Similar limitations of the structured evaluation flights appeared to affect pilot responses regarding the task demands of using the Data Link services. Two questionnaire items which asked whether the use of FIS

required too much “head-down” time or placed too much workload on the pilot received similar responses. In both cases, a majority of those responding indicated that the demands of the system were not excessive. However, one-third of the pilots were unable to form an opinion. Written comments documented in the results suggest that several pilots were concerned about “head-down” time or distraction and their potential effects. However, these pilots also indicated that such effects may be mitigated by continued practice. Thus, it appears that the short duration of the flights and the inability to track pilot impressions over repeated flights effectively prevented the questionnaire from yielding definitive data regarding workload or “head-down” requirements.

It should be noted that the original test plan called for a subset of the participants to evaluate the Data Link FIS system repeatedly over the course of several flights. This part of the plan was not carried out during the field evaluation. Presumably, data collected during such long-term usage would offer more conclusive findings regarding pilot workload and the utility of the GWS.

Other human factors issues listed in section 3.2 of this report were not addressed within the scope of the field study. The flight scenario was primarily designed to give the pilots direct experiences with each of the services as a basis for their subjective evaluations of the Data Link FIS package. However, it did not include specific activities which would permit an assessment of the extent to which pilots would make appropriate use of the services under those boundary conditions where the limitations of the system could become a problem. For example, the participants were not asked to make strategic navigation decisions based on a compressed graphical display of marginal weather conditions. In addition, explicit exercises with TIS were not conducted in situations where maneuvering decisions based on the traffic display could have been affected by the inherent time lag in updating target position.

It should be noted that the field study was not specifically designed to address these issues. However, some comments from the participants suggested that problems could arise if, for example, pilots treated the graphical weather display as if it were a real-time weather radar. Additional research would be required to determine the types of published instructions, warnings and training methods that would effectively minimize inappropriate use of the information provided by the system.

## 5. CONCLUSIONS.

The results of the structured post-flight questionnaires and the observations made during site visits support the following conclusions regarding the Data Link Flight Information Services (FIS) package.

- a. The 60 pilots who participated in this evaluation expressed a strongly positive response to the demonstrated Data Link services. The Traffic Information Service (TIS), Graphical Weather Service (GWS) and Text Weather Service (TWS) received uniformly high ratings for their utility and value to general aviation (GA) operations.
- b. The participating pilots agreed that GWS and TWS were effective aids to flight planning and in-flight decision making.
- c. The pilots also agreed that the TIS improved their abilities to visually acquire traffic and enhanced situation awareness.
- d. There was general agreement that the pilot interface used for the evaluation was easy to learn and use, once understood. However, the pilot group also suggested several hardware and software improvements to the interface which would increase its useability and minimize workload.
- e. The relatively short duration of the evaluation flights and the lack of repeated experiences with the system were largely responsible for a failure of the pilot group to achieve strong consensus on some issues. These included (1) the effects of the age of the GWS weather data, (2) the effects of compression induced distortion in the GWS maps, and (3) whether the "head-down" time or workload requirements of the system were too high.
- f. This field study was not specifically designed to determine whether pilots would make appropriate use of GWS and TIS under boundary operational conditions where the limitations of the system could negatively affect pilot decisions. However, some participant comments noted the potential for misuse caused by failures to consider the age of the precipitation data and the lack of geographical precision in the compressed maps. Because of Data Link delays, TIS could also lead to error if it were improperly used as the sole basis for guiding an avoidance maneuver at close range.

In assessing the significance of these comments, it should be noted that the inherent limitations of the FIS package are explicitly reflected in

statements of its intended uses. GWS and TIS were designed as advisory services. GWS is a strategic flight planning tool and TIS is an aid to visual acquisition of potential traffic threats. Efforts to insure appropriate use of the services have included the development of recommendations on usage limitations for incorporation with the Aircraft Flight Manual. In addition, implementation plans call for the publication of Advisory Circulars and revisions to the Airman's Information Manual (AIM) intended to inform and instruct pilots regarding appropriate usage of the FIS package.

g. The pilots agreed that their training on the use of the FIS package was appropriate. They also indicated that the typical GA pilot should receive training on the system and video-based training, supplemented in some areas by oral and/or written instructions, was the method preferred by the largest number of pilots.

h. The results indicate that a Data Link equipment purchase price of \$5,000 or less and an additional hourly aircraft rental cost of \$10 or less would be acceptable to over 45 percent of GA pilots.

## 6. RECOMMENDATIONS.

The following recommendations are based on the opinions expressed by the pilots who participated in this field evaluation, and on the assessments of the independent observers representing the Data Link Branch of the Federal Aviation Administration's (FAA) William J. Hughes Technical Center.

a. The pilots who participated in this study expressed a high level of acceptance for the Data Link Flight Information Service (FIS) package, and indicated that the services offer a significant potential for improvements in the safety and utility of general aviation (GA) operations. For these reasons, it is recommended that the FAA and industry actively pursue the implementation of this system and the development of operational airborne equipment that is affordable and effective.

b. A majority of the comments regarding desirable changes to the FIS package that were recorded during the study refer to design features that would be incorporated by avionics manufacturers, rather than changes to the ground infrastructure or the basic information provided by the system. This finding suggests that the feedback received from the pilots who participated in this study should be used

as a starting point for further work to identify minimum pilot interface requirements for the Data Link FIS package.

Design requirements to guide the efforts of manufacturers should include specifications and recommendations for display/control unit design, location, and legibility. They should also suggest a common set of conventions for user interaction which promote rapid and accurate pilot performance and minimize problems of transferring between equipment produced by different manufacturers.

c. Additional research should be conducted to answer questions that were not fully addressed by this field study. In conjunction with the effort to develop pilot interface requirements, research is needed to determine whether the pilot workload and "head-down" time demands of the system are acceptable, and if these demands are mitigated by long-term use.

Research also should be conducted to ensure the effectiveness of training materials, warnings, and instructions intended to prevent misuse of the Graphical Weather Service (GWS) or the Traffic Information Service (TIS).

## 7. REFERENCES.

Chandra, Divya C. and Bernays, D.J. *Test Plan: Dulles Data Link Field Evaluation*. MIT Lincoln Laboratory, June 1995.



APPENDIX A

STRUCTURED EVALUATION QUESTIONNAIRE  
AND DATA FROM 60 PILOTS

I-1:	Data link precipitation information increases my confidence in making a go/no-go decision (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	0	1	4	26	29	4.38	5	4	0.69
I-2:	Data link precipitation information increases my confidence in deciding whether to deviate due to weather (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	0	1	2	22	35	4.52	5	5	0.65
I-3:	Weather Information provided by data link added to my understanding of the weather situation (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	0	1	4	16	39	4.55	5	5	0.70
I-4:	Compression-induced distortion reduced the utility of precipitation maps (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	6	17	27	8	2	2.72	3	3	0.94
I-5:	Age of precipitation images (8-22 minutes) reduced utility of precipitation maps (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	4	18	17	19	2	2.95	4	3	1.02
I-6:	In general, the data linked precipitation information agreed with other information that was available (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	0	0	10	28	22	4.20	4	4	0.71
I-7:	My overall Impression of Graphical Weather Service is positive (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	0	0	0	23	37	4.62	5	5	0.49
I-8:	My overall Impression of Text Weather Service is positive (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				
	0	1	1	16	42	4.65	5	5	0.61
I-9:	I would like to have access to the Graphical Weather Service all the time (1 to 5, 5 = strongly agree)					<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>				

0	0	3	17	40	4.62	5	5	0.58
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I-10: I would like to have access to the Text Weather Service all the time  
(1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	6	15	39	4.55	5	5	0.67

I-11: Near-term availability of GWS is important to GA operations (1 to 5,  
5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	7	17	36	4.48	5	5	0.70

I-12: Near-term availability of the TWS is important to GA operations (1  
to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	9	15	36	4.45	5	5	0.75

I-13: What information was most useful when planning an in-flight  
deviation?

ID	Responses
100	en route wx maps
101	GWS
102	GWS
103	None needed, but GWS backed by TWS (investigator-induced opinion?)
104	GWS
105	TIS
106	Location of good/bad weather.
107	TIS and GWS
108	Rain intensities.
109	GWS
110	GWS
111	GWS
112	Range
113	Precipitation map, current observations
114	GWS combined with surface wx observations
115	GWS precept level
116	GWS
117	Traffic alerts, thunderstorms, convections
118	Weather information
119	FT and GW information
120	GW- current.
121	Precipitation intensities and boundaries.
122	Graphical

- 123 GWS gave good picture and the text portion provide deviation decision making data.
- 124 Weather graphics.
- 125 Graphic display of precipitation levels.
- 126 Current weather between current position and destination.
- 127 Graphical wx.
- 128 Weather.
- 129 Location of severe weather.
- 130 The weather report as text.
- 131 Graphical weather- to see rain and intensity.
- 132 Graphical Display and Text
- 133 Precipitation
- 134 Graphical Weather presentation seeing where the cells are in relation to your position.
- 135 Graphical weather + its movement by going to previous weather data.
- 136 Graphical wx
- 137 Different times GW intervals.
- 138 precipitation patterns & text weather.
- 139 Areas of Level 3 or above- i.e. graphics.
- 140 Graphical Wx and most important the TIS
- 141 Intensity and weather (precipitation)
- 142 Surface aviation reports/Graph. wx depiction
- 143 SA
- 144 The surface observations
- 145 The surface observations gave you exact numbers so that would be the deviation information
- 146 On this flight, graphics. On others, probably sequences.
- 147 Graphical
- 148 The alternate minimums and wx warnings
- 149 GW information
- 150 Graphical, followed by text. Initial decision based on quick graphical reference for general picture, followed by an examination of text data of divert airfield before decision to divert was finalized.
- 151 Weather planning
- 152 Alternate destination conditions
- 153 TIS & Text wx
- 154 FLT & GW
- 155 Text weather service
- 156 Combined use of both the graphical and text weather information is useful in both "go/no-go" decision making as well as the formulation of alternative plans of action.
- 157 The graphic wx display along w/a current SA.
- 158 Precipitation map- weather, TIS- Traffic deviation

159 Both text weather service and graphic

I-14: Are you able to relate the precipitation information to your present position?

ID Responses

100 Yes

101 N/A- No precept. Course up presentation is strongly recommended.

102 Yes

103 Yes, I think North up!

104 Yes.

105 Yes.

106 Yes, but had to think a minute.

107 Yes

108 Yes

109 Yes

110 Yes

111 Yes

112 Yes

113 Yes

114 Yes, but only to a general area of the display (e.g.- 2 o'clock about 2/3 of the way out)

115 Yes

116 Yes

117 Yes

118 Yes

119 Yes

120 Yes

121 Yes- although it would be helpful to at least have the a/c position shown on the GW display.

122 Yes

123 Yes

124 If you mean, top is always N on the screen and I am not always going north, -yes.

125 Yes, with some effort. Should be track up.

126 Yes, this is somewhat workload intensive since the displayed information is relative to ground fix instead of plane.

127 Yes

128 Yes

129 Yes

130 Yes, after some initial difficulties.

131 Yes

132 Yes

133 Yes- but making it relative to actual heading would make it useful.

134 Yes- and I like north being up.

- 135 Yes
- 136 Yes
- 137 Easily learned.
- 138 Yes
- 139 Yes
- 140 Yes- it requires a good explanation before you begin it is needed to be able to understand the direction of wx.
- 141 Yes
- 142 Yes
- 143 Yes
- 144 Yes
- 145 Yes, but private pilots with little experience might have trouble seeing the position.
- 146 Yes- Took only a while to get used to North-oriented display.
- 147 Yes
- 148 Yes
- 149 Yes
- 150 Difficult because reference is not to the present location and heading of acft. It takes a bit of mental time to correlate the presentation with my actual position.
- 151 Yes
- 152 Yes
- 153 Yes
- 154 Yes
- 155 Yes
- 156 Yes, however the addition of other geographical information e.g.: VOR's, Airports, etc., in addition to the primary reference point would aid in flight planning decisions.
- 157 Yes, very easily.
- 158 Yes
- 159 Yes

I-15: Are you able to judge how the displayed precipitation would affect your flight?

ID Responses

- 100 Yes
- 101 Would help greatly in avoidance.
- 102 Yes, by viewing different ranges
- 103 Yes.
- 104 Yes.
- 105 Yes. this was a very nice feature.
- 106 Yes.
- 107 Yes
- 108 Yes

109 Yes  
110 Yes  
111 Yes  
112 Yes  
113 Yes  
114 Gen., yes. But the inclusion of other VORs or airports w/in the  
selected range would have helped.  
115 Yes  
116 Yes  
117 Yes  
118 Yes  
119 Yes  
120 Yes  
121 Yes- It was easy to identify areas of precipitation. and find alternate  
routes.  
122 Yes  
123 Would like a scale of colors on the display to judge level of  
precipitation.  
124 Yes  
125 Yes  
126 To a degree. Combined w/ other information including things like  
cloud cover/temp...Yes  
127 Yes  
128 Yes  
129 Yes  
130 Not well enough from the graphical display- most have backup from  
weather text!  
131 Yes  
132 Yes  
133 Yes  
134 Yes, the color display makes it easy to make decisions without  
having to concentrate on the screen.  
135 Yes  
136 Yes  
137 Yes  
138 Yes  
139 Yes  
140 Yes  
141 Yes  
142 Yes  
143 Yes  
144 Yes  
145 Yes  
146 Yes

147 Yes  
148 Yes  
149 Yes  
150 Yes... that is easy  
151 Yes  
152 Yes  
153 Yes  
154 Yes  
155 Yes  
156 Yes- best if integrated with information from on-board radar and/or  
stormscope.  
157 Yes.  
158 Yes  
159 Yes

I-16: Has use of GWS or TWS changed with experience? If so, how?

ID Responses

100 The more times I called up the information, the more comfortable I  
became.  
101 N/A- First flight.  
102 Yes, with only one hour or so, very easy to use.  
103 N/A.  
104 N/A.  
105 I hope to use this system more, I feel more confident use data link  
when it is up and running.  
106 N/A- first flight.  
107 [blank]  
108 N/A  
109 No  
110 N/A- first time.  
111 Only used once  
112 Yes, as I became more comfortable with the system, I used it much  
more!  
113 N/A. 1 flight only  
114 First use of it. It seemed easier to use than calling FSS on the radio.  
115 Becomes easier with practice  
116 No  
117 much better and more careful pilot  
118 Yes, but it would be interesting in using it in bad weather.  
119 Easier to use with experience  
120 Got more comfortable with the menu.  
121 [blank]  
122 Became easier.



- 123 Yes, I have never use any airborne wx equipment. It offers an added level of safety.
- 124 Too little experience to tell.
- 125 Yes. No problem learning it.
- 126 Not at this time.
- 127 Better with experience.
- 128 No
- 129 NA. First time use, favorably impressed.
- 130 Not enough experience with the service to be able to give a meaningful response.
- 131 Yes, able to operate unit more efficiently.
- 132 Yes. From 0 Experience to Novice.
- 133 Yes- I like it, But can think a lot a things to make its use easier.
- 134 N/A
- 135 Yes, I got better for every weather requested.
- 136 No
- 137 Faster & high level of confidence.
- 138 need more time but it gets easier
- 139 Yes- Interpreted easier with use.
- 140 This was my first experience w/Graphical Weather
- 141 No, I still use it regularly
- 142 Yes
- 143 A better understanding
- 144 [blank]
- 145 The more familiar you are with the two the more a pilot would use them.
- 146 No
- 147 Yes
- 148 No
- 149 No
- 150 Not enough actual experience with the service to provide a response
- 151 No
- 152 Typical learning curve
- 153 Yes, I can develop a greater sense of the "big picture."
- 154 [blank]
- 155 Not enough time to evaluate
- 156 Insufficient experience w/system to comment
- 157 Yes, learning to interpret the charts as well as the FTs + SAs has made them of much more use.
- 158 From video to actual- 100%
- 159 No

I-17: What additional weather services/information would like to see made available through data link?

ID	Responses
100	AWOS?
101	Icing areas, IFR visibility, Sigmet boxes- overlaid on actual WX.
102	40 mile scale might help plot trends in movement of activity.
103	[blank]
104	Other information received through DUAT (i.e., Pireps, Notams, FD, etc.)
105	I like this system as it is.
106	Notams? Airport information.
107	[blank]
108	Wx depiction.
109	Any wx report available through FSS should be available on datalink
110	Approach plates. Database of airport information, airspace information, etc. Clearances. Cancellation of flt plans
111	Winds aloft.
112	Pilot reports- PIREPs
113	Sat pictures, graphic wx maps.
114	Forecast maps, SIGMETs, severe wx warnings, AIRMETS, PIREPS, more storage capacity so more than one graphical wx map can be saved and then compared with other locations or time periods.
115	Lightning displays, turbulence areas, icing areas, cloud coverage
116	Pireps, NOTAMs
117	GPS, connect to HSI
118	Storm scope.
119	Winds aloft data. Airmets/Sigmets (abbreviated). Perhaps just notice so I can contact FSS/FLT watch.
120	Forecast cell movement with upper winds.
121	I think that a full range of services, comparable to DUATs, would be beneficial to the pilot.
122	Something less expensive than Mode S.
123	ATIS/AWOS/ASOS
124	?
125	Clearance, communications.
126	NOTAMs
127	Radar picture of the US or sectors of the US.
128	[blank]
129	ATIS
130	[blank]
131	Lightening, cloud heights, base.
132	Ability to pinpoint areas of electrical activity
133	Clouds/satellite information/pictures/play back of several wx pictures to indicate a trend of wx direction, airport locations other

- than one location (ability to go to alternate airports), geographic information.
- 134 [blank]
  - 135 Winds aloft, Area forecast, Notams!
  - 136 Winds aloft, NOTAMS, weather alerts.
  - 137 Maybe some type of alert to heavy precipitation much like traffic alert.
  - 138 Not sure.
  - 139 Winds Aloft, Graphical surface observations, lightning strike data.
  - 140 Altitude could possibly be labeled on the Graphical Wx display.
  - 141 Lightning/Electrical Discharge location
  - 142 [blank]
  - 143 Pireps
  - 144 As long as I know the wx and what the wx will be I'm ok with it.
  - 145 Icing areas, turbulence, IFR conditions
  - 146 Can't think of any.
  - 147 Lightning/electrical activity
  - 148 Wx orientation relative to your heading/s
  - 149 Winds aloft, Notams, FDC Notams, ATIS information, Sigmets, airmets, pireps, Defined radius information: e.g.: IAD SA/50nm will give all SA's within 50nm of IAD!
  - 150 Winds aloft, icing conditions
  - 151 Pirep's
  - 152 Sports information/stocks
  - 153 Airport-runway frequency information, approach charts, etc.
  - 154 [blank]
  - 155 En route weather- area weather
  - 156 Winds aloft, pilot reports, Notams, Sigmets, Airmets
  - 157 AIRMETs could be useful, + maybe PIREPs for turbulence & icing conditions.
  - 158 Airport services
  - 159 Tops and bases of clouds

I-18: General comments on data link weather services.

- ID Responses
- 100 Good speed in obtaining information.
- 101 Excellent concept. Would help tremendously in decision making.
- 102 none
- 103 [blank]
- 104 I like it. Noticed I sometimes got so much involved in selecting wx or service that I tended to look inside quite a bit (VFR flight). That tendency might be reduced with more experience on the unit.

- 105 I hope that soon this becomes available to all pilots. It would make the sky a lot safer place to be with TIS, the weather data is most handy for those IFR flights, as well as for the VFR pilot.
- 106 Excellent.
- 107 Weather was 22-35 minutes old for the duration of the 1 hour flight. That is too old to be useful w/in 25 miles for deviation purposes. Uplinking process needs to be faster.
- 108 Excellent service. However, I would like to see additional graphical information. Also needs to be more current. Especially approaching destination airport.
- 109 GWS should be updated at every 10 mins at a minimum! Anything 20 mins or older is of doubtful value. Some type of notification that "new" data is available (without pilot action) should be devised. This would help reduce requests for "old" information.
- 110 [smiley face] Good Stuff!
- 111 Geographical boundaries, such as bodies of water would help with awareness of precipitation location. Or use VORs or airport IDs of nearby airports to provide better situational awareness. For small-scale depictions, all airports could be shown, but as scale is increased, only large airports could be shown to reduce clutter and time to paint.
- 112 I am really excited about this technology. The link wx service, coupled with GPS and moving map technology could significantly reduce enroute wx accidents!
- 113 [blank]
- 114 A step in the right direction toward something that can really help pilots avoid wx accidents.
- 115 Very helpful. It's an important safety element missing from GA aircraft.
- 116 Useful tool in understanding weather. Needs to be placed in center of control panel.
- 117 Excellent. I'll buy it!!!
- 118 It would be nice to know what altitude the weather is being painted for.
- 119 Excellent & Long overdue.
- 120 Add aircraft position via Loran/GPS link.
- 121 [blank]
- 122 Liked it very well. Could be used for GA if less costly.
- 123 Update time seemed reasonable. If we were allowed more sweeps, would like the screen resolution be better? I might wait longer for better resolution.
- 124 [blank]
- 125 Great concept! Can't wait until cost is reasonable and human factors are refined.

- 126 Nice overall addition to cockpit for VFR/IFR GA. I wouldn't use it to attempt to navigate around weather under IFR conditions. Embellishes the "big picture." Might be nice to have audible tone (different than traffic) when weather is ready (don't have to keep checking screen). Didn't like not being able to go back directly to main page from displayed weather without stopping at list page. Noticed scrolling buttons were in different locations for different weather products, should try to place in same location if possible.
- 127 I found it to be a very useful tool.
- 128 Real good. Had trouble reading text on the top lines.
- 129 Extremely useful. Access important.
- 130 [blank]
- 131 Service is real good- monitor is hard to read- needs better resolution. Use English for surface observations and terminal forecasts.
- 132 Liked it.
- 133 Is needed, needs to be low cost, make the system easy to operate. Specific- I would like to see the display on the dash as a heads up unit. Make regenerations of information automatic when in text mode.
- 134 Very easy to use, logical control inputs I like north being up.
- 135 I feel it is very effective although I would feel much more comfortable if it updated around every 5-8 minutes.
- 136 Good with useful information. However, it would be better if the items in #17 were added.
- 137 Anything to help VFR flight in hazy conditions avoiding thunderstorms would be helpful to me.
- 138 Appears to be a useful tool.
- 139 Engineer products to stay within range of most of GA fleet. Overall very positive.
- 140 It would prove to be a useful tool and looks as if good information can be acquired easily- but it would not be the only information I would use to plan a flight around.
- 141 Nice inflight system
- 142 Overall a great tool for IFR operations.
- 143 Very interesting and useful
- 144 The service itself seems to be ok with being only to use it for local trip VFR. The only thing I would like to see would be better graphics on the display.
- 145 The only weakness of the system is that pilots will try to use the information as inflight weather radar
- 146 It's wonderful! I wish I could afford one!
- 147 Effective/valuable

- 148 1. Update should be shorter than 15 min. 2. Moving map. 3. See  
?#17 comment. 4. Great tool for GA.
- 149 Very useful, very easy to use!
- 150 They give us something we never had before and something we can  
make use of in flight. Text data is a bit difficult to read in a  
bouncing airplane. Suggest you try to use a larger font size and add  
a scroll feature to let pilot roll it up and down as needed. You don't  
want to spend too much time staring at small print on a screen  
while trying to fly a light plane in turbulence. "Read at a glance"  
type does the trick.
- 151 Place a true north arrow in the corner of the display while in the wx  
mode
- 152 Screen was hard to see in bright sunlight from left seat- Required  
shading or leaning fairly far to right- otherwise very easy to use.
- 153 Very good and certainly a useful inflight tool.
- 154 Overall very positive impression
- 155 [blank]
- 156 [blank]
- 157 Very good!
- 158 None- Great!!
- 159 I think it's a good service for General Aviation pilots. Also traffic  
alert is a good idea.

II-1: The data link traffic display helped me to locate traffic that I might  
not have seen otherwise (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	1	8	51	4.83	5	5	0.42

II-2: The data link traffic display helped to spot traffic earlier than I might  
have otherwise (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
1	0	3	9	46	4.68	5	5	0.73

II-3: Limitations of the data link traffic display hampered my search for  
traffic(1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
26	18	13	1	1	1.86	1	2	0.94

II-4: With data link traffic display active, I did NOT look outside for traffic  
as often as I would have otherwise (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
17	20	9	11	3	2.38	2	2	1.22

II-5: The data link traffic display improved my awareness of the traffic situation (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	4	23	33	4.48	5	5	0.62

II-6: I would like to have access to the data link traffic display all the time (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	2	3	14	41	4.57	5	5	0.74

II-7: The traffic information provided by data link sometimes conflicted with information from other sources (e.g., view out the window) (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
24	13	13	10	0	2.15	1	2	1.13

II-8: My impression of the data link traffic display is positive (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	1	12	47	4.77	5	5	0.46

II-9: Near-term availability of the TIS is important to GA operations (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
1	0	8	11	40	4.48	5	5	0.85

II-10: Comments on Traffic Information Services.

ID Responses

100 Only the cost would keep me from buying this equipment.

101 none

102 The self alert phenomenon might be worth trying to eliminate. I'm not sure why that happened. We didn't get to talk about during the flight.

103 Need more prominent visual cue to TIS Traffic. More prominent bell or tone for audio alert.

104 [blank]

105 To me as a private pilot I liked this feature best! The weather doesn't change as fast as other traffic does.

106 [blank]

107 Upon receiving a traffic alert, we were able to spot the approaching aircraft 1.5 mi. (haze) at 12:00 and deviate. Quite impressive. Doubtful he ever saw us.

108 [blank]

- 109 Some type of audio tone should be used to alert pilots to threats. Single beep- new target anywhere on screen. 3 rapid beeps- any target within 2 mi. Cont. tone- w/in 1 mi. Should be able to mute warnings.
- 110 The traffic alert function helped us to see a big jet that was within a mile of and ascending into our flight path. It was very hazy and we would probably have never seen the traffic otherwise.
- 111 [blank]
- 112 Very user friendly.
- 113 [blank]
- 114 The TIS traffic alert signal (audio) should be more urgent. It didn't stand out very well from the radio and intercom inputs.
- 115 A very important service needed by GA
- 116 [blank]
- 117 Excellent. Change position display in front of pilot.
- 118 Make the tangents of other aircraft change in altitude more noticeable.
- 119 Suggest that the system allow different display scales- approach and enroute at a minimum. ~3 mi. radius for approach. ~10 mi. radius for en route.
- 120 [blank]
- 121 [blank]
- 122 Not a good tool for VFR. May be benefit for IFR.
- 123 TIS is hard to evaluate without many targets, but seemed to work ok.
- 124 [blank]
- 125 I assume that the low brightness and poor panel location of the prototype will be corrected in future commercial versions.
- 126 Great! Nice to have around FDK in summer haze. Nice to be able to cross check ATC flight following on trips. Very useful. Might be nice to have selectable range for audible alarm.
- 127 [blank]
- 128 [blank]
- 129 [blank]
- 130 [blank]
- 131 Monitor resolution needs to be better. This is a great idea!
- 132 [blank]
- 133 As most pilots are aware, heads up flying in most important, this system is another distraction and thus should be used only with experience.
- 134 Experienced #2 twice on our demo flights.
- 135 This would be a tremendous asset to pilots everywhere especially in high traffic areas.
- 136 Outstanding piece of equipment.



137 [blank]  
 138 [blank]  
 139 Fine when used in conjunction with visual efforts!  
 140 [blank]  
 141 4. There's no substitute for looking outside!  
 142 Excellent information! Thoroughly enjoyed having that information available.  
 143 [blank]  
 144 If the range could be improved (more than 5mi.), that would be much nicer particularly for traffic converging head on.  
 145 The traffic information is most needed when you in and around traffic pattern  
 146 [blank]  
 147 [blank]  
 148 1. Great tool for GA  
 149 Traffic display needs to be clearer and larger! (Higher resolution)  
 150 [blank]  
 151 [blank]  
 152 [blank]  
 153 1) Need to scale the ranges in/out, ex 2 mi/5 mi. rings reduced for terminal operations. 2) Change the "BACK" "FWD" button locations.  
 154 There is a definite need in GA for this type of accurate system  
 155 [blank]  
 156 I would suggest and adjustable "range" for the TIS, perhaps based on altitude input from the Mode S transponder. As altitude and speeds increase, the "range" could increase. Suggested intervals might be : a. 10K MSL-250kts, b. 18K MSL- Floor of Class A airspace, c. FL290-2000 ft Vertical separation/Mach spd, d. Terminal mode- Set manually to reduce "range."  
 157 [blank]  
 158 None.  
 159 [blank]

III-1: It takes a long time to learn to use the CDU (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
31	25	3	1	0	1.57	1	1	0.67

III-2: Once you understand how it works, the CDU is easy to use (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	1	3	25	31	4.43	5	5	0.67

III-3: The text of the data link display is legible (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
1	6	9	32	11	3.78	4	4	0.93

III-4: In single-pilot operations, using the services requires too much head-down time (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
6	20	21	13	0	2.68	3	3	0.93

III-5: In single-pilot operations, using the services places too much workload on pilot (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
11	28	20	1	0	2.18	2	2	0.75

III-6: In general, I was able to get the information I wanted when I wanted it (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	1	34	25	4.40	4	4	0.53

III-7: In general, I was able to get the information I wanted without making errors (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	3	7	34	16	4.05	4	4	0.77

III-8: I would prefer to use a different layout/design of the buttons/controls on the display unit (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
8	10	20	11	11	3.12	3	3	1.28

III-9: What are your suggestions for improving the CDU?

ID Responses

100 Larger number- I wear glasses.

101 A telephone style keypad would help greatly on identifiers (for the letter 'C', 3 pushes on the '2' button, 1 push for 'A'). Display could be brighter in sunlight and should be in center of panel or directly in front of the pilot if a moving map display.

102 The selection keys, when unit is installed right panel, should be on left-side of unit. Slight angular installation of unit would possibly eliminate parallax, glare, pilot distraction. Not so much a problem for mid panel mount. Increase intensity of "bright" for sunglasses, glare, etc. Color vision deficiency in some pilots may be a factor in ID'ing red-green wx intensity.

- 103 Lag in cursor response yielded overshoot, need to go around again til became disciplined to just do two pulses to get from middle char to lead char. Move to TWS not intuitive. Label problem? Name problem? Position problem? Was I over focused on GWS? Problems with CUR abbreviation?
- 104 Up-down arrows on the right side of unit are fine. Cursor/backward/forward gave me some trouble. I tended to want to push button on right hand of unit to move cursor to the right. A dial/knob to select Location identifiers would improve ability to make selection and reduce time spent looking at unit (inside cockpit).
- 105 Closer to the pilot and higher on the panel/maybe on top the dash.
- 106 [blank]
- 107 Combine the request and view functions into one step In other words, when you send for the wx, have it appear on the screen without having to push a button to view it.
- 108 Centered. Really depends on the layout of the aircraft. The Aerospatiale and Cessna SR-20 a/c would be ideal candidates for the unit. All of the functions could be easily accessible.
- 109 [blank]
- 110 The only thing I would change: when you recall or reselect stored information it is misleading. When I selected GW for FDK using recall, I assumed I was getting the most recent obs. I forgot that it was merely in memory.
- 111 Left and right cursor buttons. Due to its installation on the far right side of the panel the left side of CDU is tough to read and requires the left seat pilot to lean to the right. If center placement were available, don't think this would be a problem.
- 112 I would like to see larger sized buttons. When you are bouncing through turbulence, it is difficult to use small buttons.
- 113 Change screen colors- difficult to see with brown-tinted glasses. Screen washes out in sunlight. Scroll knob would be easier to use than buttons. Text difficult to read- larger font, plain language preferred.
- 114 Use rotary knobs for location selections, like some Loran and GPS units do. Use left/right buttons instead of back/fwd. Display should be as close to in front of the pilot as possible, at least in the center radio stack. Best option would be an integrated GPS position/graphical wx/TIS display right under the HSI/ADI.
- 115 Should be in center stack. Swap cursor fwd& bwd buttons. Eliminate button response delay. Add alphanumeric keyboard.
- 116 Center of control panel.
- 117 Either ball type mouse or yoke.

- 118 Not sure, but I think they can do a better job on how to call up 3 letter identifiers and how to change them.
- 119 Relocate buttons (functions) based on usual input. Rotary dial alpha numeric selector. Also use the same symbology/method on the ICAO ID page for airport/VOR ID input.
- 120 Display needs to be in center stack.
- 121 [blank]
- 122 Better lighting display.
- 123 Reverse the position of the fwd/back buttons. Let display jump straight to TIS screen upon alert. Mount display unit in mid console high-up. The response on the menu choices was slow. You can press the button and easily jump over your desired stop point.
- 124 The CDU should be nearer and facing more toward the pilot.
- 125 Locate display in center stack. Must be sunlight readable. Excessive number of buttons entries to obtain function. Selecting by airport ID is primitive- should be plain language.
- 126 Top line of text was hard to see for tall person dependent on where/how the CDU is mounted of course. Brightness control/range is important for operator in bright sunlight. Had some difficulty reading text w/brightness turned all the way up.
- 127 Would like brighter and clearer display.
- 128 Button layout was easy to use, display should be in the center so both pilots can use and see.
- 129 Only comment is that buttons are difficult to hit (select) when in turbulence.
- 130 I found it difficult to read the top line of the display (problem of my height and low mounting of monitor). Contrast on the screen was not good enough to see the text. Very slow response when pressing the cursor movement button.
- 131 Display should be center of console. Better resolution would make characters more distinct. Needs to be brighter.
- 132 Twist/knobs maybe.
- 133 Heads up display. I like knobs for changing VOR/APT locations.
- 134 1- Reduce unused buttons. 2- Locate centrally, however, on the right side of the 172 didn't cause me any problem.
- 135 To scroll through the alpha, a knob would be much quicker. Closer to pic on left although I could read it fine from the other side.
- 136 Reverse fwd & back buttons. Change buttons to dial knobs. In turbulence. conditions the buttons could become frustrating. Ideally the unit should be located in the center stack. The top display line was barely readable. Either start display on line 2 or mount screen in a slightly tilted position. When traffic alert comes in the screen should switch to correct page.
- 137 Center display would be best- because both pilots could use it.

- 138 Center location.
- 139 Reverse position of up/down or fwd/back buttons! Most recent wx request should automatically appear unless TIS shows threat. Any threat should bring us TIS screen!
- 140 Display could possibly be enlarged and should be mounted in the center of console. Buttons need to be places a little further apart.
- 141 Display: Left (pilot) side or center
- 142 In this particular aircraft, the way the CDU was mounted, it was hard to read the first text line. If it were mounted higher, or canted up, reading would be easier.
- 143 Maybe have a couple of buttons under the screen as well as on the sides.
- 144 I'm fine with the button layout, but location should be so that it can be seen by both seats.
- 145 [blank]
- 146 Center Radio stack
- 147 Use no "non function buttons." Reverse positions of FWD/BCK
- 148 1. Different layout/design 2. Sunlight protection
- 149 Locate unit in radio stack or on right side angled toward pilot!
- 150 Text is legible but a bit too small to read easily in a bouncing cockpit. Use larger font + add scroll feature. Display should be in middle of instrument panel, with some sort of glareshield and ability to tilt toward pilot.
- 151 Reverse the FWD + REV buttons. The display should be located near center panel.
- 152 See earlier comments about screen.
- 153 1) As noted earlier. 2) More of a center location and as close to eye level as possible. Heads up display, while not economical, would be best
- 154 Display between pilots so both can read. Possible buttons w/writing on them that brings you to a series of pg. you can scroll through. Parallax- hit the wrong button several times.
- 155 [blank]
- 156 The CDU should be located as close to the center of the panel as possible.
- 157 [blank]
- 158 No change in layout- Center of instrument panel
- 159 Display should be located on left side of cockpit for easier use in single pilot operation.

IV-1: I received an appropriate amount of training on use of the data link services (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	1	2	25	32	4.47	5	5	0.65

IV-1a: If the training was inappropriate, did you receive too much or too little training?

ID Responses

100 About right, but the simulator should be used more.

101 Would have preferred use of ground training unit.

102 Formal present. was adequate, but was several wk. before flying equip.

103 Video needs tightening. Could have done it on paper alone.

104 [blank]

105 Training was very good, not pressured.

106 [blank]

107 [blank]

108 [blank]

109 [blank]

110 [blank]

111 In only 1 flight, I feel confident with it.

112 [blank]

113 [blank]

114 [blank]

115 [blank]

116 [blank]

117 [blank]

118 [blank]

119 Better video needed.

120 [blank]

121 [blank]

122 Just about right.

123 [blank]

124 [blank]

125 Live instructor was good. Videotape was worthless.

126 N/A. Ease of use made training period/learning curve small.

127 Training was good.

128 [blank]

129 In general, 30-60 minute videos on material I am unfamiliar with are too long. I lose concentration.

130 [blank]

131 [blank]

132 N/A

133 [blank]

134 [blank]

135 Just the right amount. It's fairly easy to operate this equipment.

136 Too much. Since I knew the subject I could have done w/o the video.

137 [blank]

138 [blank]  
 139 [blank]  
 140 [blank]  
 141 [blank]  
 142 [blank]  
 143 [blank]  
 144 [blank]  
 145 Brandan Taksa of AOPA did a super job in training and explaining  
 the system to me. He researched airports that would have  
 precipitation so I could see the system work.  
 146 [blank]  
 147 [blank]  
 148 Mr. Taksa was a great instructor.  
 149 Perfect!  
 150 [blank]  
 151 [blank]  
 152 [blank]  
 153 [blank]  
 154 [blank]  
 155 Was appropriate  
 156 Just right.  
 157 [blank]  
 158 [blank]  
 159 No.

IV-2: The typical GA pilot should receive some formal training on use of the data link services (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	7	9	21	23	3.99	5	4	1.01

IV-2a: If some data link training should be given to the typical GA pilot, what training should be received and what form should it take?

Explanation of TIS display (written, oral, or video).

ID	Responses
100	oral/video
101	video
102	video
103	all
104	written/video
105	all
106	all

107 video  
108 all  
109 written/video  
110 written/video  
111 written/video  
112 video  
113 video  
114 video  
115 video  
116 written/video  
117 video  
118 written  
119 video  
120 oral/video  
121 video  
122 video  
123 video  
124 video  
125 oral/video  
126 written/video  
127 oral/video  
128 video  
129 all  
130 oral  
131 written/video  
132 oral  
133 oral/video  
134 video  
135 video  
136 written  
137 video  
138 video  
139 oral/video  
140 oral/video  
141 video  
142 video  
143 oral/video  
144 oral/video  
145 written  
146 written  
147 video  
148 video  
149 all  
150 written



151	written/video
152	all
153	oral
154	oral
155	written/video
156	video
157	oral
158	oral/video
159	oral

IV-2b: Explanation of Precipitation display (written, oral, or video)

ID	Responses
100	oral/video
101	video
102	video
103	video
104	written/video
105	all
106	oral/video
107	video
108	all
109	written/video
110	written/video
111	written/video
112	video
113	video
114	video
115	video
116	written/video
117	video
118	written
119	video
120	oral/video
121	video
122	oral
123	video
124	video
125	oral/video
126	written/video
127	oral/video
128	video
129	written/oral
130	oral
131	written/video

132	oral
133	oral/video
134	video
135	video
136	written
137	video
138	video
139	oral/video
140	video
141	video
142	oral
143	oral/video
144	oral/video
145	oral
146	written
147	video
148	written
149	all
150	video
151	written/video
152	all
153	oral
154	oral
155	written/video
156	video
157	oral
158	oral/video
159	oral

#### IV-2c: Explanation of Compression Algorithms (written, oral, or video)

ID	Responses
100	written
101	video
102	video
103	written
104	written
105	all
106	video
107	video
108	written
109	[blank]
110	written

111 [blank]  
112 written  
113 written  
114 written  
115 [blank]  
116 written/video  
117 video  
118 written  
119 video  
120 [blank]  
121 video  
122 [blank]  
123 written  
124 video  
125 oral/video  
126 written/video  
127 oral/video  
128 [blank]  
129 written  
130 [blank]  
131 written/video  
132 oral  
133 [blank]  
134 video  
135 video  
136 [blank]  
137 video  
138 video  
139 oral/video  
140 video  
141 written  
142 [blank]  
143 oral/video  
144 oral/video  
145 oral  
146 [blank]  
147 written  
148 [blank]  
149 all  
150 [blank]  
151 oral  
152 oral  
153 oral  
154 oral

155 written/video  
156 [blank]  
157 [blank]  
158 oral/video  
159 oral/video

IV-2d: Explanation of Coverage Limits (written, oral, or video).

ID	Responses
100	video
101	oral
102	video
103	written/oral
104	written
105	all
106	all
107	video
108	written
109	written/video
110	written
111	[blank]
112	video
113	written
114	written
115	written
116	written
117	video
118	written
119	video
120	written/oral
121	video
122	oral
123	written
124	video
125	all
126	written/video
127	all
128	video
129	written
130	oral
131	written/video
132	oral
133	oral/video
134	video
135	video

136	written
137	oral
138	oral
139	oral/video
140	written/oral
141	video
142	video
143	oral/video
144	oral/video
145	oral
146	written
147	oral
148	written
149	all
150	written/oral
151	written/oral
152	oral/video
153	oral
154	oral
155	written/video
156	written
157	oral
158	oral/video
159	oral

IV-2e: Explanation of Text Weather Products (written, oral, or video).

ID	Responses
100	video
101	written
102	video
103	written/oral
104	written
105	all
106	oral
107	video
108	written/video
109	written/video
110	written
111	[blank]
112	video
113	written
114	video
115	written
116	written

117 video  
118 written  
119 video  
120 written/oral  
121 video  
122 oral  
123 video  
124 video  
125 written/video  
126 written/video  
127 all  
128 video  
129 written/oral  
130 oral  
131 written/video  
132 oral  
133 oral/video  
134 video  
135 video  
136 written  
137 video  
138 oral  
139 oral/video  
140 written/video  
141 video  
142 oral  
143 oral/video  
144 oral/video  
145 written  
146 [blank]  
147 oral  
148 video  
149 all  
150 written/oral  
151 written/video  
152 all  
153 oral  
154 oral  
155 written/video  
156 video  
157 oral  
158 oral/video  
159 written

IV-2f: Practice with System on ground.

ID Responses

100	x
101	x
102	x
103	x
104	x
105	x
106	x
107	x
108	x
109	x
110	x
111	x
112	x
113	x
114	x
115	x
116	x
117	
118	x
119	x
120	x
121	x
122	x
123	
124	x
125	x
126	x
127	x
128	x
129	x
130	x
131	x
132	x
133	x
134	x
135	
136	x
137	x
138	x
139	x
140	x
141	x

142	x
143	x
144	x
145	
146	x
147	x
148	
149	x
150	x
151	x
152	x
153	x
154	x
155	
156	x
157	x
158	x
159	x

IV-2g: Suggested other training topics/types

ID	Responses
----	-----------

100	[blank]
101	[blank]
102	[blank]
103	[blank]
104	[blank]
105	[blank]
106	[blank]
107	[blank]
108	Limitations.
109	[blank]
110	[blank]
111	[blank]
112	Practice with system in air?
113	[blank]
114	[blank]
115	[blank]
116	[blank]
117	[blank]
118	[blank]
119	[blank]
120	[blank]
121	[blank]
122	[blank]



123 [blank]  
 124 [blank]  
 125 [blank]  
 126 [blank]  
 127 [blank]  
 128 [blank]  
 129 [blank]  
 130 [blank]  
 131 [blank]  
 132 [blank]  
 133 [blank]  
 134 [blank]  
 135 [blank]  
 136 [blank]  
 137 [blank]  
 138 hands on.  
 139 [blank]  
 140 [blank]  
 141 [blank]  
 142 [blank]  
 143 [blank]  
 144 Practice in the air.  
 145 [blank]  
 146 [blank]  
 147 [blank]  
 148 [blank]  
 149 Flight training with qualified person (CFI or avionics tech)  
 150 [blank]  
 151 [blank]  
 152 [blank]  
 153 Seminar w/actual unit on simulator unit  
 154 [blank]  
 155 [blank]  
 156 [blank]  
 157 Hands on in the plane w/other pilots (practice)  
 158 [blank]  
 159 [blank]

V-1: The data link services were reliable enough for operational use (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	1	3	29	26	4.36	4	4	0.66

V-2: In general, I received the requested information in timely manner (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	3	28	28	4.42	4	4	0.59

V-3: The package of services that I evaluated enhances the utility of GA aircraft (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	3	17	39	4.61	5	5	0.59

V-4: In general, the data link system performed as expected (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	1	4	21	33	4.46	5	5	0.70

V-5: I was frustrated with the system because I encountered significant operational problems with it (1 to 5, 5 = strongly agree)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
44	9	5	1	0	1.37	1	1	0.72

V-6a: Rating of overall utility of: Traffic Information Service (1 to 5, 5 = high)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	1	2	15	41	4.63	5	5	0.64

V-6b: Rating of overall utility of: Precipitation Maps (1 to 5, 5 = high)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	0	7	28	24	4.29	4	4	0.67

V-6c: Rating of overall utility of: Surface Observations (1 to 5, 5 = high)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	1	6	22	30	4.37	5	5	0.74

V-6d: Rating of overall utility of: Terminal Forecasts (1 to 5, 5 = high)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Mean</u>	<u>Mode</u>	<u>Median</u>	<u>Std.Dev.</u>
0	3	7	19	30	4.29	5	5	0.87

V-7: What types of users (in flight experience/purpose) are most likely to benefit from data link services?

ID Responses

100 VFR pilots

101 All pilots would benefit from TIS- even those not equipped because equipped A/C could avoid them. Wx is useful to anyone flying XC.

- 102 Experienced single pilot IFR. High density VFR-IFR regardless of experience level.
- 103 More experience, x-country pilots w/over 100-300 hrs. Needs seasoning to know geography, city codes, etc.
- 104 X-country flights (VFR)(IFR)
- 105 Every pilot in the sky, and every pilot's passengers.
- 106 Business GA
- 107 X-country VFR and instrument rated
- 108 Frequent flyers. Business travel or traveling with family.
- 109 Those who fly the most!
- 110 All GA pilots can benefit.
- 111 Those with airplanes that require extensive modifications to be outfitted with weather radar, i.e. new nose cone, new pad assembly, etc. Generally, more experienced. pilots who own their own a/c.
- 112 IFR rated, single pilot operations. Actually, any pilot could benefit from this.
- 113 Business, x-country flyers.
- 114 Cross-country pilots and those in high traffic areas.
- 115 TIS- all users, GWS & TWS- IFR pilots.
- 116 IFR pilots, business use
- 117 Instrument rated pilots for X country.
- 118 IMC, or marginal weather
- 119 All pilots can benefit instrument rated pilots will get a better picture. Non-instrument rated will be able to make a more informed decision.
- 120 More exp. pilots.
- 121 All types- I think it would benefit everyone from recreational weekenders to business travelers.
- 122 IFR cross country.
- 123 Cross country, IFR.
- 124 If it flies, it could be beneficial to any pilot, especially the TIS.
- 125 Every level- from student to ATP.
- 126 Pilots who travel w/their aircraft are more likely to find these services useful.
- 127 Any VFR or IFR x-country flights.
- 128 All pilots.
- 129 Pilots who do a significant amount of flying. Need to be familiar/comfortable enough not to get distracted. As it is a interactive system greatest danger is pilot distraction.
- 130 All GA pilots.
- 131 May be too much for student pilots. Cross-country would really benefit, useful for all flights.
- 132 [blank]
- 133 Cross country fliers.

- 134 All GA pilots.
- 135 All cross country pilots
- 136 TIS- all pilots. Weather- cross country flights.
- 137 VFR if cost effective.
- 138 Private pilots, recreational
- 139 General Aviation
- 140 I feel all low or high time/hour pilots can benefit. I feel low time pilot could benefit the most because of the ease of the system.
- 141 TIS: All, Wx Service: IFR Pilots, primarily
- 142 More advanced aviators. The recreational/private pilot would not get as much use as a instrument/commercial pilot.
- 143 All pilots
- 144 Instrument rated pilots flying IFR.
- 145 All general aviation pilots
- 146 Instrument rated pilots doing X-C
- 147 Anyone beyond basic recreational pilot.
- 148 IFR rated pilots for decision, VFR rated pilots for traffic advisory.
- 149 Corporate/Commercial operators
- 150 Those who fly long distances (rather than short hops for Sunday lunch) and those who fly frequently and rely on the aircraft as a means of travel.
- 151 X-country IFR
- 152 IFR pilots, X country
- 153 Business operators, corporate, IFR users, personal aircraft
- 154 Flt schools/General Aviation/Small business users.
- 155 All types of users
- 156 Professional aviators would probably derive the most benefit.
- 157 Mostly people who fly frequently, not just weekend flyers. People who fly long distances where wx can change and into congested areas.
- 158 All experience levels. However low time (new) may find it too much heads down.
- 159 Private pilot and instrument rated pilots. Student pilots.
  
- V-8: Assuming that the data link services are free, what do you think is a reasonable cost to equip an aircraft with the necessary avionics to receive the services? (Aircraft owners please specify total cost. Aircraft renters please specify cost per hour)
- ID Responses
- 100 \$2000
- 101 \$5000, Renters \$5-7/hour
- 102 That assumes a lot, but TCAS alone is probably a \$3-4k project, plus wx on top of that- the cost could go to \$5-7k for hardware.
- 103 \$3000-\$5000 or \$5-\$10

104 Don't know. Rather prefer no charge to renter/customer. If this is to  
improve safety should be for nominal fee to A/C renters.  
105 \$3000  
106 \$10/hr.  
107 Renters- add \$5.00 hours.  
108 \$5/hour.  
109 \$3000-\$4000  
110 A couple of dollars an hour.  
111 As an owner, it needs to be much cheaper than radar, which still  
has an edge in usefulness for weather.  
112 Owners- \$2000. Renters- \$10/hr.  
113 \$5/hr.  
114 \$2000  
115 \$10/hour  
116 \$5000  
117 \$5000 +/- 1500  
118 \$4000, \$2/hour  
119 +/- \$2000 for installed. \$5/hour.  
120 about \$10000  
121 \$3000-\$5000  
122 \$800-\$900  
123 Renter- \$2/hour max.  
124 Total \$1000-\$1500  
125 \$4000  
126 Owner- up to \$2000, Renter- \$70/hr.  
127 \$2000  
128 \$1500-\$2000  
129 Owners- \$3-5K, Renters- \$3-5/hour  
130 Not enough background information on avionics costs to answer  
question specifically.  
131 \$3000  
132 [blank]  
133 \$5/hr. However, there are a lot of times when this information  
would not be needed, and if turned off, should cost anything extra.  
134 Renter- extra \$5-\$15/hr.  
135 Owner: \$5-6k for equip. + install.  
136 \$10-\$15  
137 \$3500  
138 \$3000  
139 \$10,000 or less  
140 \$10/hr.  
141 An extra \$10/hr  
142 \$5/hr.  
143 \$10/hr

144 For me, a renter, as low as possible.  
145 \$6000 for owner  
146 \$1200  
147 Rent \$2/hr  
148 C-172 with data link \$80/h  
149 Owners: \$7000, Renter: \$3/hr  
150 Wishful thinking but a range of \$4000 to \$8000 would make it  
affordable to recreational or non-business aircraft owners.  
151 Owner's should be approx. \$6000.  
152 \$2-5K lower end if feasible  
153 An additional \$10/hr  
154 \$1500  
155 \$5000  
156 \$3500/aircraft  
157 As a renter, I would say \$15 per hour.  
158 \$5.00/hr  
159 \$10.00/hour

V-9: General Comments.

ID Responses

100 Thank you for allowing me to participate in this very worthwhile  
program.  
101 none  
102 Overall, this makes sense for GA A/C for the next century, if not  
cost prohibitive. Having basic IFR equipment with GPS & datalink,  
what else would you want?  
103 Test Administration: Remind test subject that he is pilot in  
command, or determine that test administrator is PIC. Statements  
that "I do radio & navigation" etc., create a feeling of student/CFI  
relationship. I let my guard down! Impacts test results on Traffic  
Watch. See and Avoid!  
104 [blank]  
105 I enjoyed this evaluation was glad to be a part of datalink testing.  
The product was what made it so exciting.  
106 [blank]  
107 Remind pilots that not ALL aircraft are transponder equipped. In  
areas where there are recreational non-transponder equipped  
planes, pilots still to look out for them.  
108 [blank]  
109 [blank]  
110 [blank]  
111 [blank]  
112 [blank]  
113 [blank]

114 [blank]  
115 A good program. Very professional testing arrangement.  
116 great system, access to Pireps and Notams should also be available.  
117 Excellent, change wx maps to instant updates, place moving map  
over wx.  
118 I liked it, but would not put a lot of faith in it if it was a rented  
plane. In my own airplane I think it would be a good system.  
119 Thanks for allowing me to participate.  
120 [blank]  
121 [blank]  
122 Nice to have, Too expensive.  
123 Good system. Would provide much utility to the avg. pilot. The one  
complaint is that you tend to keep your "head down" a little too  
much. Maybe this would improve with experience.  
124 I was impressed, especially with the increased safety factor from  
TIS.  
125 Keep up the good work! This will be a tremendous boon to the  
safety and utility of light aircraft.  
126 Nice package. Nice visibility study by AOPA.  
127 I feel it would be a very useful tool for the private pilot.  
128 Nice  
129 See #7. Greatest danger is that pilots become distracted in  
operation of equipment + forget to fly the a/c. I don't know that this  
could be totally eliminated but may be helpful to "pre-load" as  
w/waypoints on NAV equipment.  
130 [blank]  
131 This is a great step forward in general aviation.  
132 [blank]  
133 Good beginning- needs work to make it really useful to GA pilot.  
Keep it simple, identify the information most important to GA light  
aircraft pilots, and focus on those services.  
134 I would buy if I owned an aircraft.  
135 If the price is right, please send me one when available.  
136 Great unit for new equipment. Once enhancements are made such  
as additional services it will be one of the most useful tools in the  
cockpit.  
137 [blank]  
138 [blank]  
139 Hurry!  
140 [blank]  
141 [blank]  
142 Great product- Enjoyed using it!  
143 [blank]  
144 [blank]

145 [blank]  
146 [blank]  
147 [blank]  
148 1. Make surface observation information more simple 2. Lower the user cost.  
149 Keep up the good work! Let's get it certified ASAP! Great unit!  
150 Like the fact that it gives us access to information we can make practical use of while in flight, and something we never had before. Enhances in-flight decision-making and safety. Downside is fact that it can distract a pilots attention away from flying the aircraft for too long. That decreases safety somewhat.  
151 [blank]  
152 Great flight- enjoyed using the system- very useful  
153 I thoroughly enjoyed working with the unit. I look forward to its implementation.  
154 Very impressed- Great system- esp. the traffic information- had several alerts while flying and had to change course to avoid- This system works!!  
155 [blank]  
156 [blank]  
157 Impressed.  
158 Great!!  
159 Data Link services is a good service for all pilots with the other services offered (FSS, Flight Following).